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Instrument development for 21st century skills in Biology

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Abstract

This study aims to develop a valid and reliable instrument for measuring 21st century skills towards biology among Malaysian secondary school students using the application of Rasch Model. The sample of this study consisted of 433 form four students who are currently taking Biology as one of their elective subject. The instrument was developed to determine five constructs: digital age literacy, inventive thinking, effective communication, high productivity and spiritual values. The first four constructs was adapted from *enGauge 21st century skills* while the last construct was created to suit Malaysian education philosophy. Using a survey design, data were analysed based on Rasch Model for polytomous data via the computer application, WINSTEPS 3.69.1.11. The result shows that the instrument has a very high item reliability (0.91-0.98) and high person separation reliability (4.16-2.31). However for the spiritual values construct, the separation value is lower than 2.0 representing less variation and consistency of respondents. Based on the result, this instrument is beneficial for educators who are interested to evaluate the 21st century skills in term of improving student's readiness in facing a global world.

Keywords: 21st century skills; instrument; Rasch Model; reliability; validity;

1. Introduction

According to the Curriculum Development Centre (2006), the main aim of Biology subject is to provide students with the skills and knowledge in Science and Technology by enabling them to solve problems and make decisions in daily life based on scientific attitudes and moral values. The Biology syllabus was adapted to include the 21st century skills such as scientific skills, creative and critical thinking skills, science process skills and scientific attitudes and moral values. In terms of teaching and learning approaches such as questioning, constructivism, contextual learning and mastery learning, all have features to produce students with 21st century skills. However, the teaching and learning methods are not fully implemented and resulted in less of integration of 21st century skills especially for science students.

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2. Why are the 21st Century Skills a Necessity?

21st century skills emphasized on creating students who are able to apply technology through digital age literacy, are creative and critical in their thinking and possess excellent interpersonal and social skills. Based on the statements made by the partnership for 21st century skills (2002) and Kellner (2000), the technological revolution gives a great impact on the cultural life of the community. Students who lack or do not acquire the skills will face a stiff competition; this is because the skills required in the workplace will continue to increase in tandem with economic development and new technologies in the global market.

The challenges of the 21st century education are the quality of education itself and individual qualities, which includes innovative thinking. Hence, people who are educated and have the courage to change and innovate is highly regarded within the organization and subsequently will become an asset who will contribute in development, whether in education or economy (Yusof, 2008).

3. Purpose of the study

The purpose of this study is to develop a valid and reliable instrument of 21st century skills towards biology among Malaysian secondary school students. Rasch model analysis is performed to gain an empirical evidence for reliability and validity of the items developed. The items in the instrument are expected to measure the 21st century skills students have towards Biology and to identify the fit of the items to the 21st century skills constructs.

4. Developing items for 21st century skills towards Biology

There By developing the instrument of 21st century skills towards biology, a three stage process was undertaken. The first stage was to identify the suitable components as a research scale. The second stage was to build the items for each component that has been identified. And finally, the items are constructed to test the validity and reliability by using an appropriate statistical analysis.

4.1. Identification of component scale

In identifying the components of 21st century skills, review of the related literature was carried out first. The information from enGauge 21st century skills (NCREL & Metiri Group, 2003) was used as the main source for developing the 21st century skills instrument. Analysis of the literature reveals that the skills listed in enGauge 21st century skills represent the components needed in preparing students to succeed and prosper in life, in school and on the job and keep them competitive internationally (Partnership 21st century skills, 2006). Discussion and consideration in focus group i.e. researcher, educator and practitioner was done in identifying the key component from enGauge 21st century skills (Soh, et. al, 2010).

Finally, the four key components that were identified are; (i) digital-age literacy, (ii) inventive thinking, (iii) effective communication, and (iv) high productivity. The researcher has also identified an additional fifth component which is spiritual values. This fifth component is essential as it is one of the elements stated in the Malaysian education philosophy. Subsequent to that, a two rounds Delphi Technique was employed and the 21st century skills with both sub elements was further refined as shown in Table 1.

Table 1. Elements of 21st century skills' components

Components of 21st century skills	Element	Item number
Digital Age Literacy	Basic Literacy and numeracy necessary to function on the job and in society to achieve one's goal and develop one's knowledge and potential.	a1-a7
	Scientific literacy is knowledge and understanding of the scientific concepts and processes required for personal decision making.	a8-a14
	Environmental and sustainability are inculcated in students to be more sensitive to	a15-a17

	what is happening in their surroundings. It is also to participate positively in protecting and maintaining the environment.	
	Economic literacy is the ability to identify economic problem, alternative costs and benefit and predict the effects of economic changes.	a18-a20
	Ability to upgrade the skills and apply the technology in day to day life and ability to integrate and to use various types of media to communicate and to share information effectively.	a21-a25
	Global awareness is the recognition and understanding of interrelationships among international organizations, nation-states, public and private economic entities, socio cultural groups, and individuals across the globe.	a26
Inventive Thinking	Ability to handle multiple goals, tasks, inputs and modify one's thinking and attitude to be better suited to current environment.	b1-b6
	Higher order thinking	b7-b15
	Independent, able to plan for the achievement and manage time effectively.	b16-b23
	The desire to know and show interest that leads to inquiry.	b24-b30
	Highly creative to invent genuinely either personally or culturally.	b31-b36
	Willing to tackle challenging task in problem solving.	b37-b42
Effective Communication	Cooperative interaction among individuals in a group and poses leadership qualities	c1-c5
	Ability to read, manage the emotions of oneself and others during social interaction.	c6-c10
	Ability to manage technology that promotes public good and protects society and environment.	c11-c13
	Priority in telecommunication usage to work in a team and to interact with working colleagues and others.	c14-c15
High Productivity	Ability to manage and solve problems effectively and efficiently to achieve goals	d1-d6
	Analyze, evaluate information, new resources and suitable technology devices for work.	d7-d8
	Ability to produce high quality products and application of technology to increase social welfare and general well being of mankind.	d9-d18
Spiritual Values	I feel grateful to be able to learn biology	e1
	Interrelationship between knowledge of Biology with the religion and spiritual understanding	e2-e4
	Realize that the use of technology is to increase man's ability to use the nature's resources efficiently	e5
	Accepting the effort of mankind is to understand the interaction between nature and human	e6
	Religion is accepted as a way of life to lead a peaceful and harmonious life.	e7

4.2. Developing and writing items' component

In the second stage, writing and developing the items was done based on the elements classified in Table 1. Those elements were used as a source for developing a set of questionnaire with a total of 82 items. A five-point Likert ranging from Highly Relevant (1) to Not Relevant At All (5) scale was applied to allow panellists to evaluate the instrument to get the face and content validation.

4.3. Field testing, validity and reliability analysis

The third stage is field testing and it was carried out before analyzing the reliability and validity of the items in the instrument. Using survey method as one of the quantitative approach, this field testing sample consisted of a total of 433 science students from eight secondary schools in different locations in the state of Selangor, who are studying Biology as one of their elective subject. A questionnaire with 5-point agreement of Likert-type response was distributed to the samples. Data collected were analyzed to test the reliability and validity of the instrument via Winstep's software 3.69.1.11 (Linacre, 2007),

5. Reliability of Instrument-Rasch Measurement Model

Using Rasch measurement model, both items and respondents reliability were able to be analysed simultaneously. The higher the validity and reliability of the instrument, will make the instrument stronger and

stable in term of measuring what it needs to measure. The items and respondents reliability were measured through data analysis using WINSTEPS 3.69.1.11 application. Analysis of the data is shown in Table 2 below.

Table 2. Reliability of the items constructs

Construct	Reliability		Separation		INFIT MNSQ		OUTFIT MNSQ	
	Item	Person	Item	Person	Maximum	Minimum	Maximum	Minimum
Digital age	0.98	0.91	7.63	3.14	1.55	0.59	1.72	0.61
Inventive Thinking	0.97	0.95	5.72	4.16	1.48	0.76	1.80	0.77
Effective Communication	0.96	0.95	5.19	4.16	1.76	0.62	1.91	0.63
High Productivity	0.91	0.88	3.15	2.67	1.76	0.75	1.97	0.77
Spiritual Values	0.97	0.66	5.55	1.38	1.26	0.82	1.38	0.78

All reliability constructs in Table 2 above indicated the item reliability index which is within the range of 0.91 to 0.98. It shows the items reliability index was very good since it is close to 1.0 (Wright & Master, 1982). It shows that the repetition of the estimation for all construct were high if it was administrated to the different respondent group with same abilities (Wright & Master, 1982).

The items separation index shown in the data was accepted by Linacre (2007) and Bond & Fox (2007) which was more than 2.0 item separation index of the constructs was in the range of 3.15 (high productivity) to 7.63 (digital age literacy skill). Statistically, the items were separated from 2 to 7 strata or agreement level. This situation indicated the items were 2 to 7 spread occasion from square root error. However, for the person reliability as shown in Table 3, the reliability and separation person for spiritual value construct was less than the accepted limit which is represented in less variation and consistency of respondents. It can be modified by distributing the instruments to respondents based on variation in their demographic profile.

According to Table 3, only one construct shows MNSQ Outfit Maximum value that fit with the Rasch model. The construct was spiritual values (*Outfit* MNSQ=1.38). Consideration should be given for other constructs that did not fit since they were based on MNSQ Infit and Outfit index, advanced analysis should be performed to identify items that do not fit using Rasch measurement model.

6. Identification of the polarity and the item fit in measuring the 21st century skills construct

The implementation of the advanced analysis was to identify misfit items with the Rasch measurement model by recognised fit and polarity of the instrument. Polarity item analysis or point-measure correlation (PTMEA CORR) is an indicator used to indicate the movement of the item in one direction in the meaning of measured construct. Table 3 below, shows the construct in the instrument had a positive point measured correlation (PTMEA CORR). The minimum PTMEA CORR was item a24 (0.26) for digital-age literacy construct and the maximum was item c9 for effective communication skills construct. According by Linacre (2002), positive means that the item used to measures the students' 21st century skills can be accountable and valid. However, based on this analysis, item a24 needed to be distinct from the instrument since it had the lowest PTMEA CORR.

Table 3. Polarity of items' construct

No.	Construct	Reliability		PTMEA CORR		Total Item
		Maximum	Item	Maximum	Item	
1	Digital age	0.26	a24	0.63	a17	36
2	Inventive Thinking	0.44	b30/b35	0.66	b23	42
3	Effective Communication	0.47	c13a	0.68	c9	17
4	High Productivity	0.41	d2	0.67	d10/d16	18
5	Spiritual Values	0.54	e3	0.66	e4/e6	7

According Bond and Fox (2007), the fit item acceptance range for Likert scale is 0.6 logits to 1.4 logits. If the value is more than 1.4, the item is not homogeneous with other items in the same construct measurement scale. And if the item is lower than 0.6, the item indicate redundancy with other items.

Table 4. Misfit item

Construct	INFIT		OUTFIT		PTMEA CORR.	Item	Action
	MNSQ	ZSTD	MNSQ	ZSTD			
Digital age literacy	1.41	6.1	1.72	9.2	0.26	a24	Drooped
Digital age literacy	1.25	3.9	1.49	6.9	0.40	a9	Drooped
Inventive thinking	1.47	6.4	1.58	7.4	0.56	b25	Drooped
Inventive thinking	1.48	5.8	1.55	6.3	0.44	b35	Drooped
Inventive thinking	1.32	4.0	1.80	8.6	0.44	b30	Retain
Effective communication	1.76	9.4	1.91	9.9	0.47	c13a	Rephrasing
Effective communication	1.38	4.8	1.54	6.4	0.53	c15	Rephrasing
Effective communication	1.51	6.2	1.53	6.2	0.55	c13b	Rephrasing
Effective communication	1.52	5.8	1.52	5.9	0.55	c12	Rephrasing
High productivity	1.52	6.5	1.97	9.9	0.41	d2	Rephrasing
High productivity	1.76	9.0	1.78	9.0	0.52	d1	Rephrasing

Analysis findings from the Table 4 above indicated 11 misfit items in the instrument. Total of the engaged items and constructs were digital age literacy= 2 items; inventive thinking skills= 3 items; effective communication= 3 items and high productivity= 2 items. From all number of misfit items, only 4 will have to be dropped from the instrument, 1 item was retained since it did not give high impact to the misfit item in the construct and 5 items were rephrased since they were still needed in the instrument. If the items were dropped, the misfit item will still exist but without distinction in MNSQ OUTFIT data.

7. Conclusion

The development of an instrument to measure the integration of 21st century skills among students in Biology subject will examine the level of existing skills among students. By measuring the skills level, teachers, stakeholders and policy makers will be able to identify the weaknesses and deficiencies and needs of students. This instrument also provide ideas for teachers to become more creative and innovative in modifying their teaching methods to meet the requirements of the 21st century, and not just focus on the standards that must be met in the school curriculum. Furthermore, student-centered learning activities and the integration of real-world tools will enhance student 21st century skills especially in the global world of technology and thus help them meet its' challenges and competitiveness head on.

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